Cosmic ray dose rate determination using a portable gamma-ray spectrometer

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Introduction

Cosmic rays usually contribute only a few percent of the total dose of a TL sample. At very high altitudes the cosmic dose becomes much more important (e.g. Prescott & Hutton, 1988).

An interdisciplinary study from Bern University is trying to reconstruct the environmental history and the climatic change of the Altiplano in the Andes of northern Chile (Messerli et al., in press). In this study TL dating plays an important role besides other dating techniques.

Some approximate calculations on samples from this project showed that cosmic rays contribute up to 40 % of the total dose. It was therefore desirable to measure the cosmic dose rate at the sample locality itself. The aims of this study were as follows:

(i) to draw up a calibration curve for our 4-channel γ-spectrometer when the probe was unshielded;
(ii) to establish the shielding effect of a rock column of various depths at various altitudes;
(iii) to quantify the influence of high cosmic dose rates to channels 1 (K), 2 (U) and 3 (Th).

A comprehensive introduction to the complex subject of cosmic radiation and its implications concerning TL dating is given by Prescott & Stephan (1982). See also Prescott & Hutton (1988) and Aitken (1985, Appendix I) for further information.

If one searches for dose rate values in the free atmosphere things become difficult very rapidly. Basic research has been done by Rossi (1948; see also references therein). More recent papers have been published by Lowder & Beck (1966), Kyker & Liboff (1978) and Sztanyik & Nikl (1982). The dose rate values given in these papers show certain differences which may have many reasons (see Kyker & Liboff, 1978 and Sztanyik & Nikl, 1982 for further information). We have put together the data from these three more recent papers (see fig. 1) and calculated an exponential curve fit. With an assumed error of 12 %, all points fall within the curve. This seems reasonable, since the estimated calibration error for the CIT ionization chambers is about 17% (Carmichael, 1971).

The Harwell 4-channel γ-spectrometer type 95/0928

All measurements were carried out using this instrument, which contains a NaI(Tl) crystal scintillator of 44.5 mm dia x 50.8 mm. The instrument was calibrated in the Research Laboratory for Archaeology in Oxford according to the procedure described by Murray (1981). An alternative calibration method has been proposed by Sanzelle et al. (1988). (For instrumental properties and settings see Tables A1 and A2.) The setting of the discriminator channel allows no response to terrestrial γ-rays (Aitken, 1985). According to data published by Allkofer & Grieder (1984), the discriminator channel is sensitive to both hard and soft components. The low background values obtained in the Bern C-14 Laboratory (Table A3) correspond to 40 ppm K_2O, 18 ppb U and 80 ppb Th. This is equivalent to a total γ-dose rate, calculated using the conversion factors of Nambi & Aitken (1986), of 7 μGy/a. These figures are considered to be negligible and therefore no background correction has been made to calculate concentrations.

Measurements

The measurements made in Chile were carried out at altitudes of between 130 m and 5150 m and at geomagnetic latitudes of between 22.5° S and 24.3° S. All field readings are adjusted to a latitude of 47° (Bern). The mean latitude correction factor for the data from Chile is 1.049 (taken from fig. 2, Prescott & Stephan, 1982). Measurements in Switzerland were made at altitudes of between 420 m and 4554 m. The measurements in the glacier ice of the Monte Rosa Massif (Switzerland/Italy) were made in a borehole of ~15 cm diameter. The measurements on the glacier surface were made in two different ways: with the probe standing upright and with the probe lying flat. This was done because of the shape of the NaI crystal.

All measurements were made on well exposed sites, which is important because surface irregularities influence registration geometry, as was demonstrated in a short experiment in Switzerland. The count rate in the discriminator channel increases by about 20 % when the horizontal distance from a 60 m high wall of rock increases from 5 to 200 m.

The measurements made using the unshielded probe are plotted in fig. 2. An exponential curve computed through all points has a correlation coefficient of r^2 = 0.995. On 12 different sites, measurements at depths ranging from 50 to 7350 g/cm^2 of rock were made to find out whether a given count rate corresponds to the same dose rate using both the shielded and unshielded probe (fig. 3). For the unshielded probe the dose rates were taken from fig. 1. For the shielded probe the dose rates were estimated using fig. 1 as well as data published by Prescott & Stephan (1988) - see also discussion. The results for the shielded probe differ clearly from those for the unshielded one, although the data are few and have a considerable uncertainty.

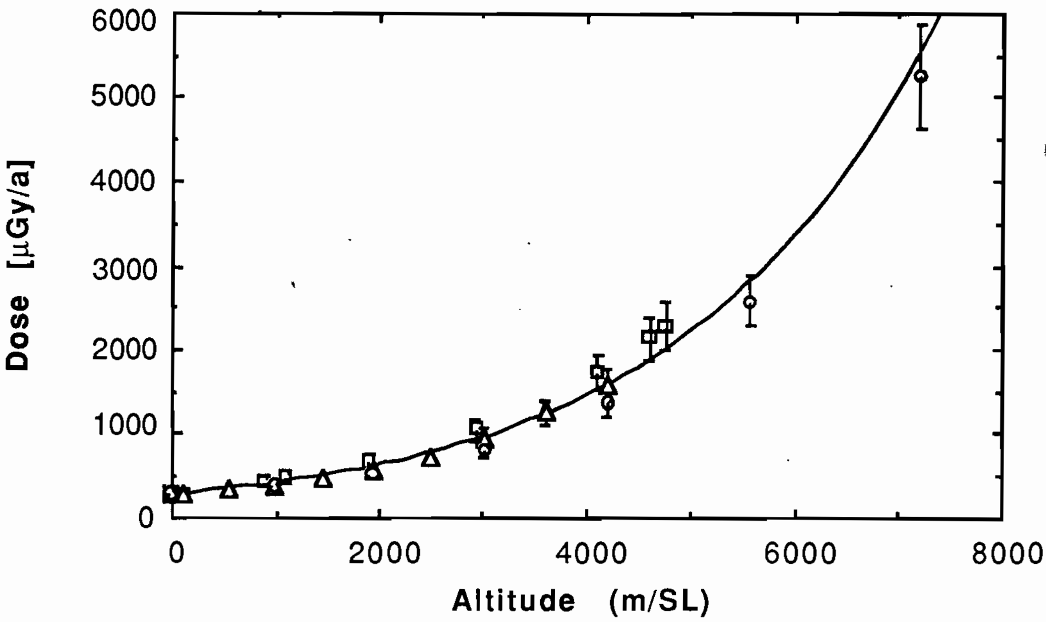

Figure 1.

Key: o - *Kyker and Liboff (1978);* □ - *Sztanyik and Nikl (1982);* Δ - *Lowder and Beck (1966).*

Dose rate of cosmic radiation (hard and soft components) as a function of altitude. The curve is calculated using all three data sets where: y = 273.2 $\log_{10}$(1.81E-04x); r^2 *(corr. coeff.)* = 0.987.
The data set is based on the ICAO standard atmosphere (1013.2 hPa at sea level, 15 °C).

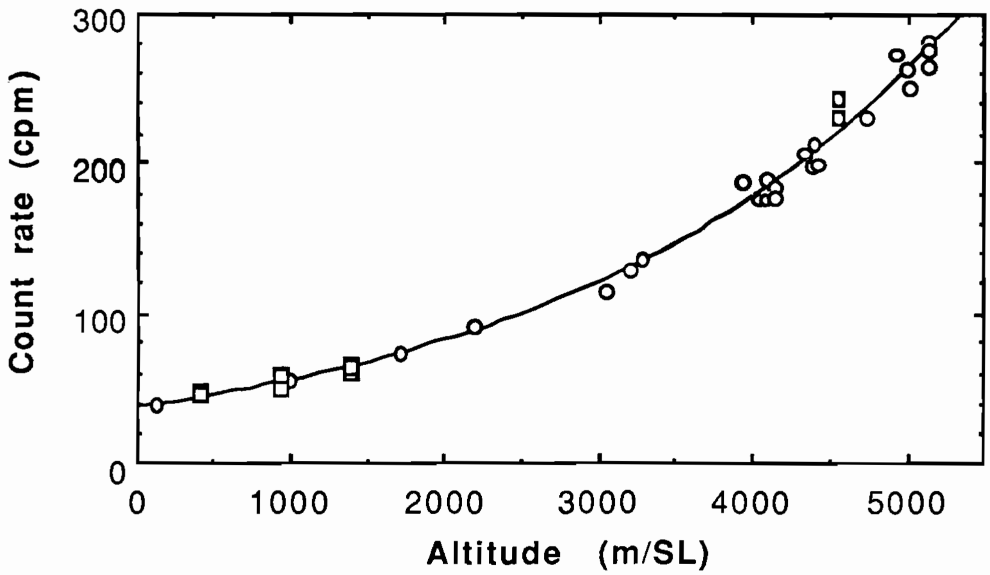

Figure 2.
Key: o - *data from Chile,* □ - *Data from Switzerland*
Count rate in the discriminator channel as a function of altitude. All count rates are adjusted to a latitude of 47°N (Berne). Curve fitted to data: y = 37.7 $\log_{10}$(1.68E-04x) ; r^2 = 0.995.

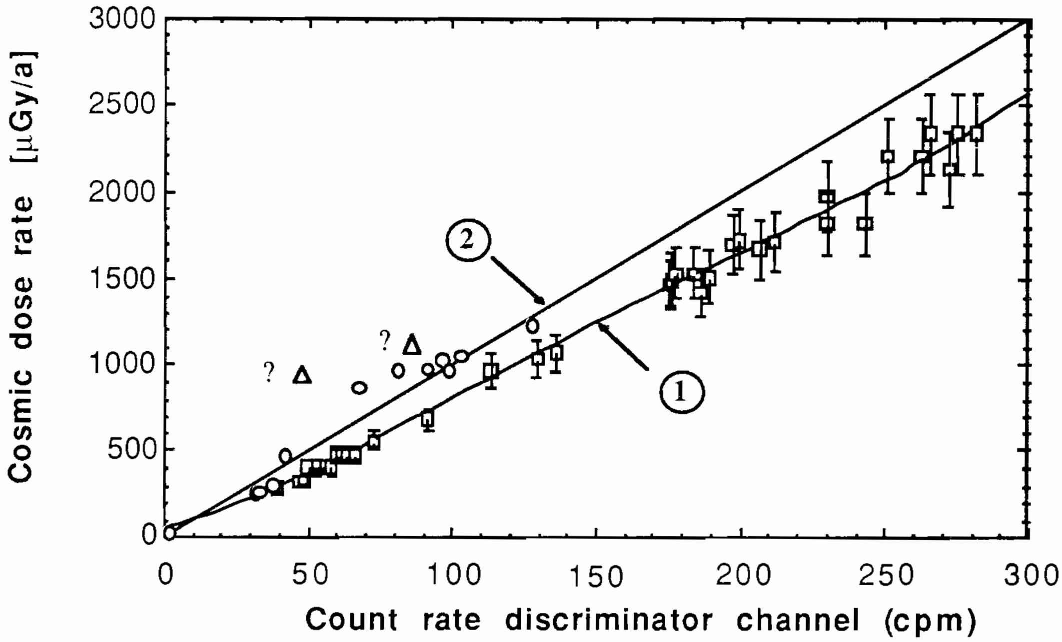

Figure 3.
Key: o *- underground measurements (shielded probe);* □ *- surface measurements (unshielded probe);* Δ *measurements in glacier ice.*
Curve fit calculated for the unshielded (polynomial fit 4th order) and the shielded (= buried) probe (regression line), respectively, where:
Curve 1) $y = 51.6 + 4.22x + 5.5E\text{-}02x^2 - 2.7E\text{-}04x^3 + 4.5E\text{-}07x^4$ $(r^2 = 0.991)$
Curve 2) $y = 10.5x - 14.1$ $(r^2 = 0.957)$
The results from the measurements in the glacier ice have not been used to calculate the regression line, because the dose rate cannot be determined with sufficient accuracy (see text).

Discussion

Since cosmic radiation is influenced by numerous factors which could not be taken into account, some simplifications are necessary in order to interpret the results in a general way:

(i) All measurements were made close to solar maximum (Solar Geophys. Data, 1990), and we have to assume that the results obtained are valid for the whole solar cycle.

(ii) The measurements were carried out at any time of the day and in any weather conditions. Any possible uncertainty caused by varying atmospheric pressure or clouding are not taken into consideration.

(iii) The data published by Lowder & Beck (1966), Kyker & Liboff (1978) and Sztanyik & Nikl (1982) refer to the dose rate in air. The figures given in Aitken (1985) and Prescott & Hutton (1988) refer to material of rock like composition. According to Sztanyik & Nikl (1982) and Prescott & Hutton (1988) the difference between the dose rate in air and that in rock is barely significant and certainly within the experimental error. These restrictions must be borne in mind when interpreting the results.

A straight line calculated through the points representing the data obtained using the unshielded probe has a negative intercept on the y-axis. This may be due to the changing ratio of the hard to soft component in the vertical direction of the atmosphere (Rossi, 1948; Prescott & Stephan, 1982) as well as to the different sensitivity of the NaI crystal towards the hard and soft component. The plot of the data obtained using the unshielded probe (fig. 3) is therefore a superposition of several non-linear functions. The lack of data at low dose rates also contributes to the negative intercept on the y-axis. One would expect an approach of the curve to the x-axis towards the origin. Since the expected count rate at sea-level is about 38 cpm (see fig. 2), it is impossible to obtain results for low count rates. We have therefore calculated a polynomial fit (expression (1) in fig. 3) for the data obtained using the unshielded probe (fig. 3). The intercept of 51.6 seems rather high, which may also be due to the lack of data at low count rates. For count rates in the discriminator channel between 50 and 300 cpm the cosmic dose rate can be approximated by:

$$\dot{D}\ [\mu Gy/a] = 8.5 \times (cpm_{discr.-ch.}) - 54.3,$$

where cr = count rate in cpm

The data obtained using the shielded probe (fig. 3) have a significantly lesser correlation than the data obtained using the unshielded one. One important reason for this is that the density and the water content of the overlying sediments could not be determined precisely. Furthermore, the measurements were made at varying depths below the surface and at varying altitudes. As a result each measurement corresponds to conditions where the intensity and the ratio of hard to soft component are different. The dose rates can only be estimated using the values from fig. 1 together with the relative variation of the soft component with depth (fig. 1 of Prescott & Hutton, 1988). Although the uncertainty is quite large, the results obtained using the shielded probe show one important fact: The measurements diverge significantly from those obtained with the unshielded probe. This can only be explained by the higher sensitivity of the NaI crystal to the hard component compared to the soft component. The dose rate obtained using the shielded probe can be calculated approximately using formula (2) in fig. 3.

At low altitudes (i.e. below 800 m) the present data do not allow a distinction to be made between the dose rate at a depth of < 100 g/cm^2 and that at the surface, although the difference is significant (see fig. 1 of Prescott & Hutton, 1988). At an altitude of 4080 m, for example, the difference is measurable for a smaller mass thickness. Here the measured dose rate at the surface is 18 % higher than that at a depth of around 70 g/cm^2 .

The measurements made in the glacier ice were not used to calculate the regression for the shielded probe, because the exact attenuation factor in ice is not known. The points plotted in fig. 3 were calculated using an attenuation factor of 10% per 100 g/cm^2 (Prescott & Hutton, 1982). Unfortunately the saddle-shaped geometry of the glacier also introduces some uncertainty as far as concerns the precise estimation of the dose rate for these two measurements; the horizontal flux of the cosmic radiation might be somewhat increased.

In order to get precise values for a good calibration of the γ-spectrometer, however, one should bury TL dosemeters at all depths and altitudes, but the results presented here are sufficiently accurate for our dating purposes.

The measurements made in the Monte Rosa Massif clearly show that there is a weak but significant dependence of the count rates in channels 1 to 3 on the count rate in the discriminator channel. It was noticed that the direction of the probe axis in relation to the vertical has an important influence on the count rate: all channels give a clearly lower count rate when the probe is vertical. This is to be expected for the discriminator channel because of the shape of the NaI crystal. Since channels 1 to 3 show the same feature, we have to assume that they are also influenced by cosmic radiation. If this were not the case, i.e. if the count rates in channels 1 to 3 were only due to terrestrial gammas, the count rates should be roughly the same in both cases, whether the probe was standing or lying. In the absence of precise values for dust and other impurities embedded in the glacier ice we estimate that about one-third of the count rate in channels 1 to 3 originates from these impurities and from nearby rocks. About two-thirds of the count rate therefore represents cosmic radiation.

Although channels 1 to 3 are influenced to roughly the same extent, the Th is much more affected than U and K (see Table A1, equations to calculate the concentrations of K_2O, U and Th). A count rate of 100 cpm in the discriminator channel leads to an over-estimation of a few ppm for K_2O and 0.15 ppm for U. A count rate of 50 cpm in the discriminator channel results in an over-estimation of the Th concentration of 0.375 ppm. We propose therefore a correction for the K and U channel if the count rate in the discriminator channel exceeds 100 cpm and a correction for the Th channel if the count rate (cr) in the discriminator channel exceeds 50 cpm using the following formulae:

$$cr\ (eff.)_{ch.\ 1} = cr\ (meas.)_{ch.\ 1} - 0.017\ cr_{discr\text{-}ch.}$$

(for $cr_{discr\text{-}ch.}$ > 100 cpm)

$$cr\ (eff.)_{ch.\ 2} = cr\ (meas.)_{ch.\ 2} - 0.020\ cr_{discr\text{-}ch.}$$

(for $cr_{discr\text{-}ch.}$ > 100 cpm)

$$cr\ (eff.)_{ch.\ 3} = cr\ (meas.)_{ch.\ 3} - 0.019\ cr_{discr\text{-}ch.}$$

(for $cr_{discr\text{-}ch.}$ > 50 cpm)

Conclusions

The data presented here show that it is possible to determine the cosmic dose rate with sufficient accuracy using an unshielded probe. With the shielded probe it is still possible to make a first approximation of the cosmic dose rate.

The influence of high cosmic radiation on channels 1 to 3 can be corrected to prevent over-estimation of K_2O, U and Th.

Acknowledgements

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H. Loosli, J. Faïn, D. Miallier. We also thank G.A. Wagner for his review and helpful comments. D. Wagenbach and his team generously placed their infrastructure on the Monte Rosa at our disposal. Field assistance by M. Grosjean and M. Vuille is gratefully acknowledged.

Table A1. Window settings

Channel No.	Isotope	Peak Energy (MeV)	Energy Window (MeV)
1 (K)	^{40}K	1.461	1.385 - 1.535
2 (U)	^{214}Bi	1.764	1.685 - 1.835
3 (Th)	^{208}Tl	2.615	2.464 - 2.764
Discriminator	cosmic rays (muons/electrons)		> 3.4

Table A2. Stripping factors and sensitivity coefficients (using terminology by Sanzelle et al., 1988). Owing to two minor misprints, the equations for α_1 and β_2 given in this paper have been corrected to:

$$\alpha_1 = -\frac{u_1}{u_2} - \frac{u_3}{u_2}\left\{\frac{\frac{t_2}{t_3}\cdot\frac{u_1}{u_2} - \frac{t_1}{t_3}}{1 - \frac{t_2}{t_3}\cdot\frac{u_3}{u_2}}\right\}; \quad \beta_2 = -\frac{\frac{t_2}{t_3}}{1 - \frac{t_2}{t_3}\cdot\frac{u_3}{u_2}}$$

Stripping factors:

$t_1/t_3 = 0.533$; $t_2/t_3 = 0.597$;

$u_1/u_2 = 0.960$; $u_3/u_2 = 0.012$

Sensitivity coefficients: k_1 = 45.25 cpm / [% K_2O]

u_2 = 4.88 cpm / [ppm U]

t_3 = 2.145 cpm / [ppm Th]

Equations to calculate the concentrations of K_2O, U and Th:

K_2O [wt-%] $= (2.21\ n_1 - 2.12\ n_2 + 0.051\ n_3)\ 10^{-2}$

U [ppm] $= (20.64\ n_2 - 11.95\ n_3)\ 10^{-2}$

Th [ppm] $= (-\ 0.564\ n_2 + 46.95\ n_3)\ 10^{-2}$

where n_1, n_2 and n_3 are count rates (cpm) in the K-, U- and Th- channels respectively.

Table A3. Instrumental background (cpm)

Locality	Discr. chnl (cpm)	K chnl (cpm)	U chnl (cpm)	Th chnl (cpm)
Low level counting lab, Phys. Dept., Bern	1.918 ± 0.039	0.370 ± 0.017	0.188 ± 0.012	0.173 ± 0.012
C-14 Lab, Harwell, U.K.	24.3 ± 0.3	0.809 ± 0.06	0.448 ± 0.04	1.009 ± 0.07

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Alternative laboratory illumination: 'gold' fluorescent tubes

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Introduction

In the process of arranging a laboratory for TL work, initially concerned with quartz, consideration was given to the appropriate illumination, taking account of recent reports on the variability in the optical transmission properties found in different batches of nominally identical filters (Spooner and Prescott 1986, Smith 1988). In order to avoid using filters around 'white' fluorescent tubes, a search through technical specifications provided by manufacturers was made for a fluorescent tube which emitted light only within the wavelength range found to be satisfactory by Spooner and Prescott (1986), that is with no significant emission at wavelengths shorter than about 500 nm. 'Gold' tubes supplied by Thorn EMI Lighting were selected. According to the manufacturer's data (Thorn EMI Lighting 1987) they do not emit at wavelengths shorter than 510 nm, which compares well with the commonly used 'Cinemoid No. 1' filter with a cut off at 470 nm and with the 'Chris James No. 179' filter recommended by Spooner and Prescott (1986) with a cut off about 490 nm. The emission spectrum from these 'gold' tubes is peaked at 590 nm falling to zero on either side at about 510 nm and 750 nm (Thorn EMI Lighting 1987). While initially the concern was with quartz TL which determined the choice of fluorescent tube type, later work concerned feldspars and optically stimulated luminescence and these are also considered below.

Illumination conditions

The samples investigated were illuminated in two different ways. In one arrangement the samples were placed at a distance of 1 m below a single 1200 mm long 40 W gold fluorescent tube. From the data on the tube, Thorn EMI Lighting (1987), the illumination intensity in this situation is calculated to be about 0.1 W m^{-2} (neglecting any reflection from walls or ceiling). In the other arrangement, the normal room lighting comprising 6 pairs of ceiling mounted 1500 mm white tubes was replaced by gold tubes of the same length rated at 65/80 W. The 'off-white' painted room measured 6 m x 7.5 m x 3 m high and the samples were exposed on a table surface 0.75 m above the floor. A relative measurement of the level of illumination in the latter situation showed it to be about twice that in the former.

The samples investigated

Quartz, feldspar and a mixed mineral sediment were used in the tests. The quartz samples were prepared from 'acid washed sand' (supplied by BDH Ltd., Broom Road, Poole BH12 4NN, England) which was ground down, separated by sedimentation to nominally 2 - 10 μm size and deposited on stainless steel discs 12 mm in diameter by 0.2 mm thick with about 3 mg of material per disc. The feldspar samples were prepared similarly from a microcline feldspar of Norwegian origin. The mixed mineral material came from a French lake sediment with standard fine grain preparation.

The TL fading tests

For all the TL measurements, sample heating and application of beta dose the equipment described recently (Galloway 1990) was used. The sample heating rate was 5 °C/s. The TL was detected by an RCA 8575 photomultiplier preceded by a 2.5 mm thick 5-58 filter and a 4 mm thick HA-3 heat absorbing filter.

For the TL fading tests on the gold lighting, each sample was drained of natural TL by heating to 500 °C and exposed to a ^{90}Sr beta source for a set time. Different beta exposure times were set for quartz, feldspar and the sediment to account for their different sensitivities. After exposure to the gold light for a chosen time each sample was pre-heated at 200 °C for 60 s and the TL glow curve recorded to 500 °C. Reference glow curves for no exposure to gold light were obtained using the same sequence of measurements. Samples were also stored in the dark for the duration of each test and then measured to ensure that no fading was taking place regardless of the influence of the light. Sample to sample normalisation was based on similarly measured TL, integrated over the temperature range 210-500 °C, resulting from equal radiation doses given to all members of the set of samples used for a particular sequence of tests.

An overall indication of fading due to exposure to the gold light is provided by the dependence of the 210 - 500 °C integrated TL intensity on the duration of the exposure and is shown in fig.1. The error bars drawn on the points in fig. 1 correspond to ±3% uncertainty in the normalised TL intensities, the value indicated by tests on sets of 10 identically treated samples not exposed to the light. Exposure to the gold light has no noticeable effect on quartz although both feldspar and the

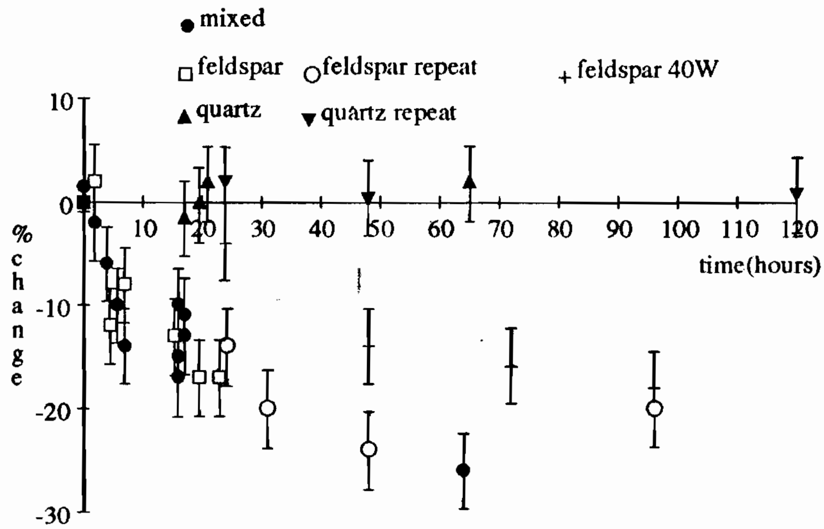

Figure 1.
Percentage change in TL intensity related to duration of exposure of quartz, feldspar and mixed mineral sediment samples to gold fluorescent lighting. The points labelled 'repeat' were measured 4 months later than the original ones.

sediment which has a feldspar component are significantly bleached by prolonged exposure.

As would be expected for the feldspar samples exposed to the single 40 W gold tube at 1 m, the halving of light intensity compared with the room lights results in about half the fading. Indeed for exposure times of up to 6 hours to the 40 W tube at 1 m fading effects cannot be clearly distinguished from random fluctuations in the measurements, fig. 2, although least squares fitting of a straight line to this set of data indicates a fall of about 4 % in TL intensity over the 6 hour period in accord with the trend in fig.1.

Four months after the first tests on the gold room lights a repeat set of tests on samples of quartz and of feldspar were carried out with results consistent with the first set, fig. 1.

Gold light exposure and glow curve shape

Looking at the recorded glow curves in more detail, no significant change in shape was observed due to exposure to the gold light. Such small variations as did occur were no more than could be seen in the comparison of glow curves from identically treated samples, due possibly to variations in thermal conductivity from heater to sample material. A quantitative investigation of possible change in glow shape for both quartz and feldspar is illustrated in fig. 3.

Consider first the case of quartz. Spooner, Prescott and Hutton (1988) studied the wavelength dependence of the bleaching of quartz TL and found the 325 °C peak to be bleached by visible light and the 370 °C and 480° peaks to be sensitive only to UV. Fig. 3a concerns the TL intensity from these three peak regions of the glow curves (integration ranges 320-335 °C, 365-380 °C, 475-490 °C respectively) for up to 5 days exposure to the gold room lights. No statistically significant change in intensity is observed, the percentage changes being -2±3 for the 325 °C region, +4±8 for the 370 °C and +13±11 for the 480 °C region. Spooner, Prescott and Hutton (1988) indicate that for 590 nm light, the peak in the emission spectrum from the gold tubes, complete bleaching of the 325 °C quartz TL should require about 10^4 J m^{-2} and so for our estimated intensity of 0.1 W m^{-2} should take about 30 hours. That substantial bleaching of the 325 °C region is not observed in fig. 3a even in 120 hours could have three possible explanations, now considered in turn.

One is simply that our estimate of gold light intensity is substantially too high. Unfortunately absolute measurement of the light intensity was not possible but it seems unlikely that calculation from the manufacturer's data should be in error by as much as a factor of 2. Even an order of magnitude lower intensity than calculated should still, on the basis of the Spooner, Prescott and Hutton (1988) measurements, show an effect within the 5 days covered by fig. 3a. An attempt to observe some bleaching of quartz TL by the gold light was made by placing samples at a distance of only 5 cm from the 40 W gold tube for 24 hours. The light intensity incident on samples at 5 cm from the 120 cm long tube is calculated to be 40 times that at a distance of 1 m when allowance is made for the extended nature of the light source.

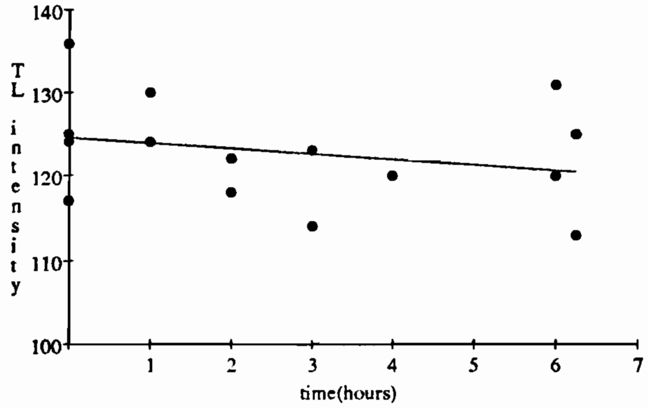

Figure 2.
Normalised TL intensity in arbitrary units for feldspar samples exposed for various lengths of time to a single 1200 mm 40 W gold fluorescent tube at a distance of 1 m. The straight line least squares fit to the data indicates a fall of TL intensity of 4% in 6 hours.

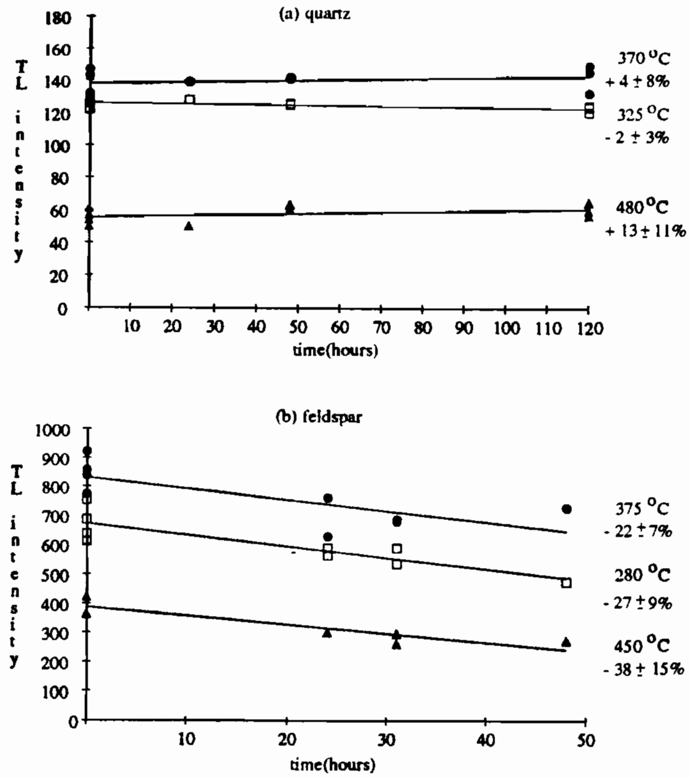

Figure 3.
(a) Normalised TL intensity in arbitrary units at 325 °C, 370 °C and 480 °C from the glow curves for quartz samples exposed for up to 120 hours to the gold room lights.
(b) Normalised TL intensity in arbitrary units at 280 °C, 375 °C and 450 °C from the glow curves for feldspar exposed to the gold room lights for up to 48 hours.

For each temperature there are 10 measured points in (a) and 9 in (b) although not all individually distinguishable on the plot. The lines are least squares fits to the measurements and the percentage change in normalised TL intensity indicated by each best fit line over the maximum exposure period is given to the right of the line.

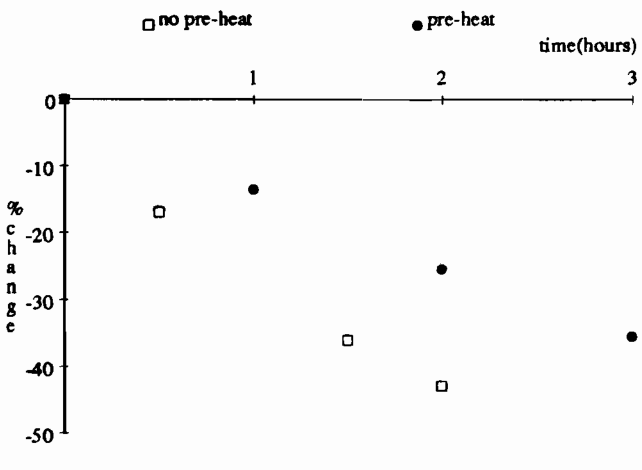

Figure 4.
Percentage change in intensity of infra red stimulated luminescence from feldspar related to the duration of exposure of the samples to the 40 W gold fluorescent tube at 1 m. The pre-heated samples were heated for 60 s at 200 °C prior to luminescence measurement.

Comparing the TL emission of 3 samples exposed for 24 hours at 5 cm with 3 samples stored in the dark indicates a percentage change of -10±7 at 325 °C, -6±4 at 370 °C and -4±4 at 480 °C. Thus bleaching of the quartz TL requires a considerably higher light intensity than arises in the laboratory illumination under test. Qualitative observation of the effect of exposure of our BDH quartz to white fluorescent light does clearly show the preferential bleaching of the 325 °C region of the glow curve.
A second possible explanation is that this quartz is less sensitive to light than the samples of quartz from several Australian sources used by Spooner, Prescott and Hutton (1988). All that can be added in this connection is that one set of tests at the 5 cm exposure position on a quartz of quite different origin gave similar results to those quoted above.
A third possibility is that the rate of bleaching is intensity dependent, being slower at low intensity. The intensity used in the measurements at a comparable wavelength by Spooner, Prescott and Hutton (1988) was about 250 times the calculated intensity for the 40 W gold tube at a distance of 1 m, but only about 6 times the intensity at 5 cm from the tube.
It is not certain which of these possible explanations is dominant or whether more than one applies. In relation to laboratory lighting it would be prudent to bear the second possibility in mind. *(see postscript)*
Similar data on feldspar is provided in fig. 3b along with least squares fitted lines, although restricted to 48 hours exposure to the room lights as fig. 1 indicates that linear fitting may not be appropriate for longer times. Allowing for the uncertainty in the slopes of the fitted lines the shape of the glow curves do not change significantly, the observed percentage changes over the 48 hour period being -27±9 for 275-290 °C, -22±7 for 370-385 °C and -38±15 for 445-460 °C.

Gold light and OSL

Infra red stimulated luminescence from feldspar is much more rapidly bleached by exposure to the gold light than is the TL signal as shown in fig. 4 for samples exposed for up to 3 hours to the 40 W tube at a distance of 1 m. Results are shown both for samples which were heated at 200 °C for 60 s to empty thermally unstable traps prior to luminescence measurements and for samples which received no pre-heat treatment. The latter show a larger bleaching effect than those pre-heated. The luminescence has been integrated over a period of 100 s, a time sufficient for most of the luminescence to be included in the integration. Sample to sample normalisation was based on the intensity of 1 s OSL from each sample prior to exposure to the gold light. Samples stored in the dark over several hours showed no loss of OSL intensity.

Conclusions

The gold fluorescent tubes provide a useful alternative to the use of filters around white tubes with greater convenience and no possibility of problems from filters overheating. Quartz TL, in relation to which the tubes were selected, is unaffected by long exposure to the gold light, up to 5 days having been tested with full room illumination. Feldspar TL is much more affected and exposure must be limited in time and intensity for negligible bleaching, say to no more than 2 or 3 hours under a 40 W tube at 1 m. Infra red stimulated luminescence is quite rapidly bleached by the gold light and for samples pre-heated to empty unstable traps, a 1% reduction occurs in only 4 minutes for light from a 40 W tube at a distance of 1 m. It is worth noting from the shape of the bleaching curves that simple linear interpolation from the effect of a long light exposure to estimate the effect of a short exposure will under-estimate the short exposure effect. Comparison with past work suggests that not all quartz is equally sensitive to gold light.

Postscript

Prescott and Fox (1990) have now shown that the TL emission at 325 °C from quartz is at a shorter wave-length than the TL at neighbouring temperatures and that the 325 °C TL may be emphasised by use of a combination of UG-11 and 7-59 filters. Measurements with this filter combination show a bleaching of 35% at 325 °C for 4 hours exposure to the gold room lights, whereas measurements with 7-59 filter show only 5 % bleaching and the 5-58 filter used in the work above shows no significant effect. The original purpose of the investigation of the gold tubes was for high temperature TL work on quartz which had been zeroed thermally and for which they are suitable. However, they are not appropriate for use while handling quartz extracted from sediments when the 325 °C TL peak is the predominant interest.

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Compiled by Ann Wintle

Errata- Pairs precision in alpha counting

Referring to p12 of *Ancient TL* 8(2), equation 7 should read:

$$D_\beta = 67.0\,\alpha_u + 104.7\,\alpha_h$$
$$= 67.0\,\alpha - 37.7\,\alpha_h \quad (7)$$

and equation (9) should read

$$D_\beta + D_\gamma = 153.6\,\alpha_u + 162.0\,\alpha_h$$
$$= 153.6\,\alpha - 8.4\,\alpha_h \quad (9)$$

On p14, equation (11) should read

$$D_\alpha = 1645\,\alpha - 166\,\alpha_h \quad (11)$$

and in equation (13) the suffix should be removed from δp_k.

I apologize to readers who have been mystified or mislead. I am grateful to Stephen Stokes for pointing out these errors.

Computer Column

Networking computers for data collection and analysis is becoming increasingly feasible for the TL laboratory. The following is one such example.
Ed Haskell

Computer networking for a TL dating research laboratory

G.A. Ennis*, S.L. Forman§ and V.J. Bortolot+

With the ever-increasing volume of data collected by TL laboratories, data management is becoming plagued by two problems: (1) reliable, convenient storage of data and (2) overcoming difficulties with remote data analysis. Previously, both data management problems were dealt with through a time-consuming backup and/or transfer of data on floppy disks. We have established a comprehensive data management system for a TL laboratory by networking together all data collection, management and analysis functions. (Fig.1) The result is a flexible environment for fast, convenient data management with the capability of remote data analysis, storage, backup and printing.

Network capability was achieved by connecting four personal computers together using a Tiara (Mountain View, CA) Arcnet topology (2.5 MB/sec data transfer rate), coaxial cable, and a passive network hub. A single IBM-compatible 2 MB 12 Mhz 286 AT-type personal computer (PC) with two 40 MB hard drives functions as a non-dedicated fileserver and the primary data analysis workstation. Three 8088-based IBM-compatible PC's, with 640 KB ram, 8087 math coprocessors, and 40 MB hard drives, perform as data collection and secondary analysis stations. These computers were previously fully dedicated during data collection. New software (Fresh Technology, Gilbert AZ) allows access to the individual hard drives even during data collection runs. Network peripherals are connected to the file server and include an Everex (Fremont CA) Excel Stream-60T cassette tape drive (60 MB per tape) for backup and archiving of data and a Panasonic KX-P4450 laser printer for text and graphic output. Each data collection station is also attached to an inexpensive local printer. An uninterruptable power supply (UPS)is recommended for the file server to protect it from power disruptions.

Data collection is accomplished through the use of one Daybreak Nuclear and Medical Systems model 1100 automated TL system and two Daybreak modular TL systems attached to PC's. The automated system uses a serial interface in contrast to the modular unit which has a parallel interface. This allows one PC to handle both the automated system output and the output of one modular Daybreak system (although not at the same time). Consequently, all data collection is performed with just two PC stations, freeing one 640 KB "spare" station and the non-dedicated file server for data analysis and management functions. We run our data collection software from the local hard drive of each station, rather than over the network, to avoid potential degradation in performance that could arise from a network slowdown during transfers of very large files.Novell (Provo, Utah) ELS Netware 286 Level I is used to support up to four nodes (three stations plus file server) allowing workstations access to server directories. Fresh Technology's "Map Assist" allows the server direct access to data on the workstation hard drives. When these are used in conjunction with the Daybreak TLAPPLIC program, workstation and server files can be entered even while data collection is in progress (with the exception of the active file). Access to file management, word processing and other software is also maintained. Other versions of Netware support additional nodes, although most require a dedicated file server and version 2.12 will reportedly not recognize a math coprocessor in a non-dedicated file server (N. Laux, personal communication, 1990). A variety of other network architectures (Ethernet, etc.) and hardware configurations are also available. In any event, we recommend consultation with, and installation by, a qualified network dealer. After installation, laboratory personnel should be able to handle ongoing network management which consists primarily of keeping a clear record of data transfers and occasional changes to custom menus and security clearances.

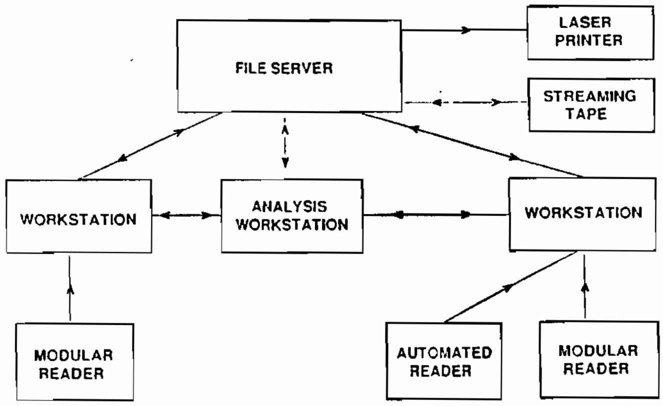

Figure 1. Network Schematic

The networking of data collection, analysis and storage has facilitated intensive research strategies allowing visiting and resident scientists and students to concentrate on more thorough study of the limitations and promises of TL dating. We are willing to discuss the further development of network capability and offer assistance in establishing similar networks in other laboratories.

We thank Nick Laux of Solution Technologies, Boulder, Colorado for his help and perseverance in establishing our network configuration.

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